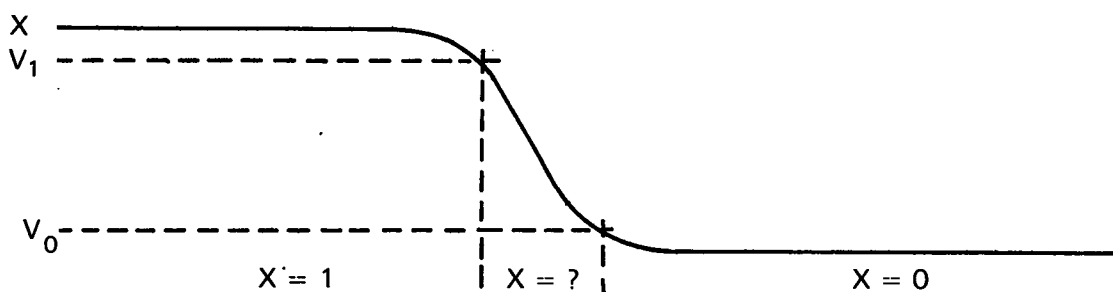


# NASA TECH BRIEF



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## Computer Program Detects Transient Malfunctions in Switching Circuits



### The problem:

To devise a computer program that will determine the response of large combinational and sequential switching circuits to given input changes, taking into account any malfunctions due to races, hazards, and oscillations, and flagging these as they occur. (Races, hazards, and oscillations are defects that occur in circuits while switches or relays are in the transient state between their two stable states). Other programs do not take into account malfunctions due to races and hazards, necessitating tedious manual analysis of the circuit to locate them.

### The solution:

A new program which accepts a system model in the form of Boolean equations and solves these equations using a ternary algebra. This application of ternary algebra to the solution of Boolean equations introduces a third or indeterminate state between the "on" and "off" states of binary algebra.

### How it's done:

Although ideal binary variables can take on only two values, the "binary" transition in an electronic circuit is actually a continuous function, as shown in the figure, rather than a discrete one. The variable  $x$  in the figure is considered to be a 1 when it is above  $V_1$  and a 0 when it is below  $V_0$ . During the time the signal is between  $V_0$  and  $V_1$ , its value is said to be indeterminate and could be either a 0 or a 1. In fact, it could simultaneously affect one logic gate as a 1 and another as a 0, depending on the electrical characteristics of the gates. Electromechanical devices also experience transient behavior in that relay contacts are indeterminate during the time the relay is operating or releasing. The effects of unexpected transient behavior are particularly evident in electronic devices where secondary response time is on the order of signal propagation time.

Basically, ternary simulation operates in the following manner: When an input variable is to change

(continued overleaf)

states, say from 0 to 1, it is first set to the indeterminate state. The equations for the system are then solved using ternary algebra to allow the effects of the indeterminate state to be propagated throughout the logic system. The input transition is completed by setting the input variable to its final state (1) and again solving the equations. When a set of variables in the logic system remains in the indeterminate state, a race has occurred. When a variable is in the 0 (1) state before an input transition, goes to the indeterminate state during the input transition, and returns to the 0 (1) state upon completion of the transition, the possibility of a static hazard exists.

In analyzing the circuit, the program provides a step-by-step account of the states of all elements. In addition, the program has the ability to solve the equations selectively; that is, when an element changes state, only those equations affected by the change are solved.

**Notes:**

1. Ternary simulation is just as applicable to solid-state switching circuits as it is to relay type circuits, and should thus be of interest to manufacturers for analyzing any type of electronic switching circuits.
2. Inquiries concerning this innovation may be directed to:

COSMIC  
Computer Center  
University of Georgia  
Athens, Georgia 30601  
Reference: B67-10002

**Patent status:**

No patent action is contemplated by NASA.

Source: Edward L. Calvin of  
North American Aviation, Inc.  
under contract to  
Manned Spacecraft Center  
(MSC-604)